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Does the environmental gain of switching to the healthy New Nordic Diet outweigh the increased consumer cost?

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ABSTRACT

The New Nordic Diet (NND) was designed by gastronomic, nutritional and environmental specialists to be a palatable, healthy and sustainable diet containing 30-40% less meat than the Average Danish Diet (ADD), ≥75% organics, and more locally grown wholegrain products, nuts, fruit and vegetables. In this study, the NND was based on economic modelling to represent a "realistic NND bought by Danish consumers". The objective was to investigate whether the ADD-to-NND diet-shift has environmental consequences that outweigh the increased consumer cost of the diet-shift. The diet-shift reduced the three most important environmental impacts by 16-22%, mainly caused by reduced meat content. The surcharge to consumers of the ADD-to-NND diet-shift was €216/capita/year. In monetary terms, the savings related to the environmental impact of the diet-shift were €151/capita/year. 70% of the increased consumer cost of the ADD-to-NND diet-shift was countered by the reduced socioeconomic advantage associated with the reduced environmental impact of the NND.

Keywords: ADD (Average Danish Diet), Environmental impact, LCA (Life Cycle Assessment), NND (Optimal well-being, development and health for Danish children through a healthy New Nordic Diet), Socioeconomic cost.

1. Introduction

On a global scale, agricultural production consumes large amounts of resources and releases large amounts of greenhouse gases (7.3–12.7 Gt CO_2-eq, or 14–24% of total global emissions; Vermeulen et al. 2012), air pollutants, nutrients, and pesticides. In 2011, Danish agriculture contributed with 0.01 Gt, or 17% of the total Danish greenhouse gas emission (Nielsen et al. 2010). Agricultural production alters soil structure and carbon storage in the soil, contributes to eutrophication, diminishes biodiversity, and causes unintended toxic effects on flora and fauna, including humans. Whereas the growing and production of feed, food and beverages have serious impacts on the environment, we all have to eat and drink. But what we choose to eat and drink greatly affects the environmental impact on ecosystems, human well-being and resource expenditure. Our choice of diet is our own, although it is often associated with ethnicity, social status, habit, age, and sex and is influenced by policy and economics (Steptoe and Pollard 2005).

Production of livestock and dairy products typically cause greater environmental impacts than the production of cereal, fruit, vegetables and legumes (Audsley et al. 2009, Tukker et al. 2011, Saxe et al. 2013, Saxe 2014). Reducing the content of animal produce, particularly meat, and increasing the content of grain products, fruit and vegetables in the typical Western diet would decrease the environmental impact of eating and drinking (Weidema et al. 2008).

This study is part of the Danish multidisciplinary OPUS project that develops, tests, and aims at disseminating a New Nordic Diet (NND). The NND was designed by gastronomic, nutritional and environmental specialists to be a palatable, healthy and sustainable diet of Nordic origin containing 35% less meat than the Average Danish Diet (ADD), more fish, wholegrain products, nuts, fruit, berries and vegetables, locally grown food in season, and more than 75% organic produce (Mithril et al. 2012, 2013, Poulsen et al. 2014). The impact of an ADD-to-NND diet-shift on climate change (Saxe et al. 2013) and on a wider range of environmental impacts (Saxe 2014) has already been investigated. The first of these studies was based on the OPUS dietary recommendations (Mithril et al. 2012), while the second was based on 180 OPUS recipes for the NND.

In the present study we apply an economic model to fulfill the above-mentioned NND dietary recommendations in the most incentive-compatible way, i.e. composing the most realistic NND bought by the population of Danish consumers.

The Objective of this study was to investigate the environmental consequences of an ADD-to-NND diet-shift – in "real life" – and if the socioeconomic value of these consequences outweigh the increased consumer cost of the diet-shift.

2. Methods

The ADD is the reported Danish consumption of foods and beverages in 2010 as represented in the consumer household survey published by Statistics Denmark (2013). The consumer survey displays the composition of the food and beverage budget on COICOP (United Nations, 2014) commodity categories, and these budget components are converted to physical quantities using consumer price data estimated on the basis of household purchase data from a commercial market survey company (GfK).

The ADD serves as the point of departure for determining the composition of the NND. In particular, the composition of the NDD is estimated by adjusting the items in the ADD by means of an economic simulation model developed for the purpose, which describes the consumers' preferences, such as preference-based substitutability between different food and beverage commodities. For example, if two commodities are close substitutes, an increase in the price of one of these products would induce a relatively strong shift in the consumption of these two commodities – the consumption of the commodity with increased price will decrease relatively strongly and the consumption of the other product will increase. In contrast, if a commodity is not very substitutable with other products, the consumption of this product will only be affected to a limited extent. Hence, sensitivity to price changes (measured by price elasticities) reflects commodity substitutability. Because substitutability between food and beverage commodities - both with regard to nutritional value and with regard to their appeal to consumers' preferences - varies significantly, the adjustments in the consumption patterns will also vary accordingly. Price elasticities (reflecting substitutability between food and beverage commodities) have been estimated econometrically on the basis of the above-mentioned commercial market survey data from GfK for five income classes of households.

Compared with the ADD, the NND involves a number of restrictions, including lower bounds for the intake of some products (categories of fruit, vegetables, seafood and whole-grains) and upper bounds for other elements (meat, sugar, saturated fat). These restrictions are implemented in the economic model by calculating the set of (implicit) prices that would be consistent with the restricted diet in utility-maximizing equilibrium. In addition to ensuring compliance with the requirements to the NND, the implicit prices also induce specific changes in the consumption of each individual commodity, as a consequence of the above considerations about substitutability. Hence, the consumed quantities are estimated by adjusting the ADD figures by means of implicit price changes and price elasticities, and these estimated quantities are multiplied by the original market prices in order to calculate the households' food budget in the NND.

The environmental impact of the ADD and the NND was compared based on 15 impact categories (carcinogenic and non-carcinogenic toxicity, respiratory inorganics, ionizing radiation, ozone layer depletion, aquatic and terrestrial ecotoxicity, nature occupation, global warming, acidification, aquatic and terrestrial eutrophication, respiratory organics, photochemical ozone effects on vegetation, and non-renewable energy; Weidema 2009), which were monetized to evaluate the overall effect in "shadow price" associated with an ADD-to-NND diet-shift. In this context, the term "shadow price" signifies the environmental cost of the diet-shift.

The comparison was based on consequential life cycle assessment (cLCA) using the Simapro 8 software, and the international Ecoinvent (Ecoinvent 2014) and the Danish LCA food databases (2004), and the Stepwise method to calculate the environmental impact and the external environmental cost (shadow price) (Weidema et al. 2008, Weidema 2009). When the LCA food and Ecoinvent databases lacked information, supplementary data that best fit the Danish production conditions were taken from the literature. All environmental impacts were for each food or beverage item calculated according to the ISO standard 14040 (2006). The consumer price was found in order to calculate the consumer cost of the diet-shift in order to relate this to the shadow price.

CLCAs seek to identify the environmental consequences of a decision or a proposed change in a system under study (oriented to the future), which means that market and economic implications of a decision may have to be taken into account (Earles and Halog 2011). The functional unit was 1 person year's diet measured in kg manufactured food and beverage products. Waste is included in the calculations to the extent that the diets are made up of what is produced for diets, not what is consumed, i.e. the waste from the farm gate to the table is included. The scope of the study included the response of 15 environmental impact categories associated with all

activities, energy, and resource consumption from soil to supermarket. However, for clarity, only data for the three most important impact categories (in terms of monetized impacts) is presented in the Figures 1 to 3.

The ADD was the reference against which the environmental impact of the NND was measured. In this study, the ADD was represented by 66 food and beverage products or categories supplied to the average Dane for private consumption. However, the products were pooled into 53 categories to fit the available cLCA data. For the graphic representation in Figures 1 to 3, all foods and beverages were further pooled to into 11 categories to ensure a lucid presentation.

In the present paper, we only study effects of the ADD-to-NND diet-shift based on the difference in the dietary composition, while in previous NND studies the commodity import distances and production strategy (conventional vs. organic) were taken into account (Saxe et al. 2013, Saxe 2014). At the present level of aggregation it neither makes sense to include the impact of import distances nor to include effects of the production strategy since these vary between individual products in each of the product categories assumed for this study. As an example the category "cheese" include imports from several different countries (import distances), where cheese of each origin can be of either conventional or organic origin, all sold to consumers in Denmark. In the present study, the focus is on the "real life" NND modeled to be bought by Danish consumers, its consumer price and shadow price.

Substituting animal produce with vegetables, legumes, whole grain products and fruit may reduce the intake of protein and some essential nutrients. In this study the ADD and the NND had similar energy and protein contents. This was obtained using the above-mentioned price elasticities for backward calculation of "implicit prices". These implicit prices represent the prices that would give the consumers the incentive to choose a diet with unchanged energy and protein contents, but with a dietary composition consistent with the NND specifications. But in addition to ensuring fulfillment of the NND-specifications, these implicit prices also determine the consumption of individual products within the commodity groups, which was the basis for the cLCA. Hence, only diets with similar energy, protein and nutrient content may be directly compared.

For effective and comprehensible presentation of the potential of the ADD-to-NND diet-shift in reducing the environmental impact of diets, the annual mileage driven in a Euro class 5 passenger car was used reference (Ecoinvent 2014).

We tested one more diet in this study – a so-called "SensWell" modification of the ADD diet (SW-ADD). SensWell is a research project that develops and tests new healthy and satisfying foods and drinks that though improved taste may substitute unhealthy foods and drinks in the daily diet. In the SW-ADD, soft drinks are replaced with a theoretical designer drink with a high *umami*. *Umami* is the 5th faculty of taste (besides sweetness, sourness, saltiness and bitterness), commonly found in its salt form as the food additive monosodium glutamate. For that reason, scientists consider *umami* to be distinct from saltiness. *Umami* is detected through specialized receptor cells present on the human and other animal tongues due to detection of the carboxylate anion of glutamate. *Umami* can be described as a pleasant "brothy" or "meaty" taste with a long lasting, mouthwatering and coating sensation over the tongue. 0.2 liter of the designer drink was assumed to be consumed by a third of the mature population every workday to replace soft drinks at "snack time". Our models show that it would not only replace a certain amount, i.e. about 15% of the total Danish consumption of soft drinks, but also other beverage and food, noticeably meat, e.g. beef and pork because of its high "*umami* content".

3. Results

The composition of the studied ADD and NND are given in Table 1. According to the NND dietary recommendations, tomatoes, cucumbers, coffee, tea, cocoa, wine, beer, and spirits of non-Nordic origin should not be part of the NND since they are not of Nordic origin. However, in the present version of the NND they are accepted at the level recommended in the Danish dietary guidelines (Astrup et al. 2005) based on the expectation that few people will do without these commodities in "real life". And as already stated, this paper aims at studying the Danish implementation of the NND in "real life". Table 1 shows that the modeled NND contains 39% less meat than the ADD, which are the OPUS NND recommendations of a 30-40% reduction.

The NND mass is 13.9% larger than that of the ADD mainly caused by a higher content of fruit and berries, vegetables and grain products. Fruit, berries and vegetables have higher water content than most other commodities and their mass is together with grain products genuinely larger in the NND (Figure 1).

Table 1 The mass and consumer price of each of the 53 food and beverage products or categories supplied to the Danish population in 2010 named the Average Danish Diet (ADD). The ADD is the reference to the modeled New Nordic Diet (NND)

Ingredients	ADD, Kg/ capita/y	ADD, €/ capita/y	NND, Kg/ capita/y	NND, €/ capita/y
Apples	8.6	22.0	13.7	39.1
Bananas	7.4	19.0	11.6	30.1
Beef, veal	13.8	118.3	9.4	80.6
Beer	57.1	74.6	74.3	101.4
Berry fruits	2.1	32.7	16.7	319.9
Bread, sand cakes, cookies, biscuits, pasta products	58.4	207.5	42.9	141.4
Butter, butter containing spreads	4.4	29.0	0.0	0.0
Cabbage	7.5	13.4	10.7	18.3
Canned fruits, fruit salads	1.4	3.8	1.4	3.7
Cheese	13.8	109.3	12.5	102.1
Chocolate (dark, not filled)	4.9	61.0	4.6	59.1
Citrus fruits	10.5	20.7	39.1	116.9
Coffee, tea, cocoa	9.4	63.2	8.0	73.8
Dried fruit, nuts	2.7	39.7	2.7	39.7
Dried vegetables	0.5	2.1	0.5	2.1
Eggs	9.4	31.0	9.6	31.6
Flour, grains	105.8	58.2	179.1	77.0
Fresh and frozen fish	1.6	31.9	2.1	40.5
Fruit juice	22.9	34.0	22.8	34.3
Ice cream	20.6	37.7	16.9	31.0
Jam, honey, candy, raw marzipan, other sugar products	14.9	101.6	12.3	97.7
Lamb	0.91	13.2	0.9	12.8
Lettuce, Chinese cabbage, parsley	5.4	24.9	5.7	27.5
Margarine, all kinds	5.7	11.5	2.4	4.9
Mineral water, incl. soft drinks	79.7	80.5	82.1	81.9
Other fresh meat	0.3	2.7	0.3	2.7
Other fruits	4.1	16.0	3.0	12.0
Other milk products	8.1	32.5	8.0	32.2
Peaches, plums, cherries, avocados	8.9	17.1	13.6	27.6
Pears	1.4	5.9	1.9	8.7
Pizza, spring rolls, other cakes	6.6	35.8	4.3	25.6
Pork	11.0	88.9	6.3	50.9
Pork fat	0.3	0.6	0.3	0.6
Potato products	2.1	15.2	1.7	12.4
Potatoes	32.3	28.2	49.0	44.2
Poultry	9.2	66.5	3.6	26.2
Processed and mixed vegetables	13.1	38.0	9.3	26.8
Processed fish, fish products)	8.3	50.1	10.2	60.7
Processed meat	3.5	23.3	3.5	23.2
Rice	7.9	10.4	8.0	10.5
Root crops, onions, mushrooms	24.6	43.8	54.2	77.2
Semi-skimmed, skimmed & buttermilk, infant formula	92.3	61.9	72.1	48.0
Shellfish (not canned)	1.1	10.8	1.5	15.3
Smoked and salted fish	0.6	12.4	0.6	13.4
Soup, sauce, bouillon, flavor products, yeast, preservatives	19.6	72.1	19.7	73.3
Soured whole milk, yoghurt	22.2	36.0	19.8	32.2
Sugar	3.5	8.9	0.7	1.9
Tomatoes, cucumbers, pepper bells, peas	18.1	62.1	19.7	69.6
Variety & cold meat, bacon, sausage	13.6	161.7	7.9	94.8
Vegetable juice	0.4	2.2	0.3	2.1
Vegetable oils	3.2	8.9	4.	11.5
Whole milk	11.3	10.3	8.1	7.3
Wine, port-, fruit- & dessert wine, champagne, spirits	44.5	206.3	44.5	206.6
Total	**841**	**2369**	**958**	**2585**
NND increase relative to the ADD	**100%**	**100%**	**13.9 %**	**9.1 %**

The NND reduced the environmental impact relative to the ADD measured by 12 of the 15 impact categories. The socioeconomically most important impacts (in terms of monetized impacts: respiratory inorganics, i.e. fine

particles < 2.5 µm in aerodynamic diameter ($PM_{2.5}$), nature occupation and global warming) were all decreased by 16% to 22%, mainly caused by the reduced meat content in the NND (Figure 1). According to the LCA food database (2004) and the Ecoinvent database (2014), meat has a higher environmental impact per kg than most other commodities, and therefore dominates the environmental savings associated with the ADD-to-NND diet-shift.

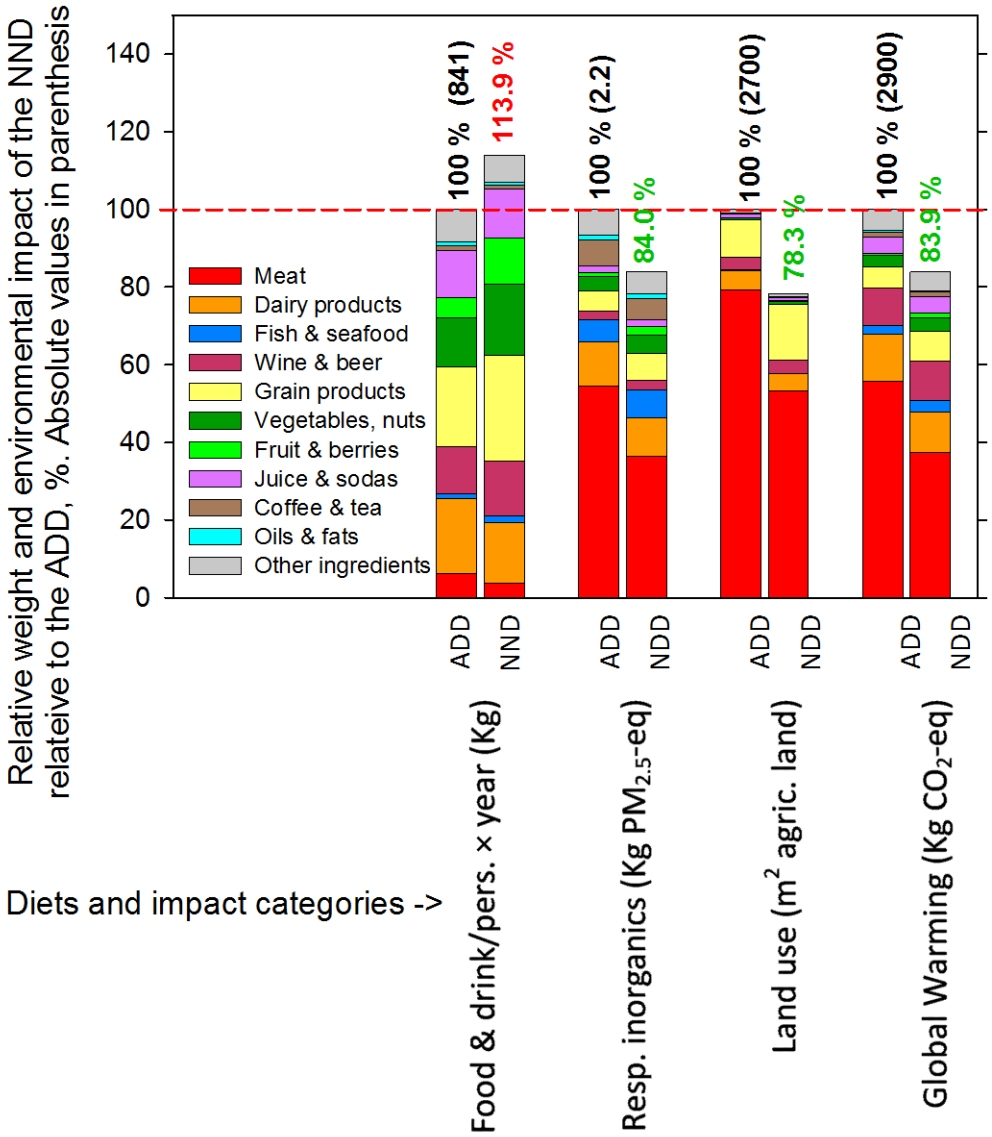

Figure 1 The quantities consumed and selected environmental impacts of the Average Danish Diet (ADD) and the modeled New Nordic Diet (NND) showing the environmental benefit of the ADD-to-NND diet-shift.

The absolute values in Figure 1 are given in parenthesis, e.g. 2900 kg CO_2-eq released per capita and year with the ADD, and 16.1% less for the NND (2440 kg CO_2-eq). It should be noted, that the land use change (LUC) was included in the global warming calculations as implemented by Saxe (2014). The inclusion of LUC (using values taken from Audsley et al. 2009) more than doubled the difference between the GWP of the ADD and the NND and nearly doubled the difference between the overall (monetized) environmental impacts of the two diets (Saxe 2014). The content of meat and dairy products in both diets dominate in each of the three environmental impact categories.

The environmental cost to society (shadow price) of the ADD was found to be €820 and that of the NND €669 (Figure 2). The ADD-to-NND diet-shift therefore potentially saves society for €151/capita/year in terms of improved environmental conditions. Figure 2 shows that the meat content of both diets dominate the shadow price most through its impact on nature occupation and global warming and least through the sum of remaining impact categories. The second most important impact on nature occupation is grain products. The ingredients in the "sum of remaining impact categories" that dominate the environmental cost (shadow price) are sweets, coffee and cocoa. Fish and seafood have its highest relative impact on respiratory inorganics ($PM_{2.5}$; Figure 1, 2). This impact is caused by the considerable diesel consumption of fishing boats and the ice for onboard storage of the catch.

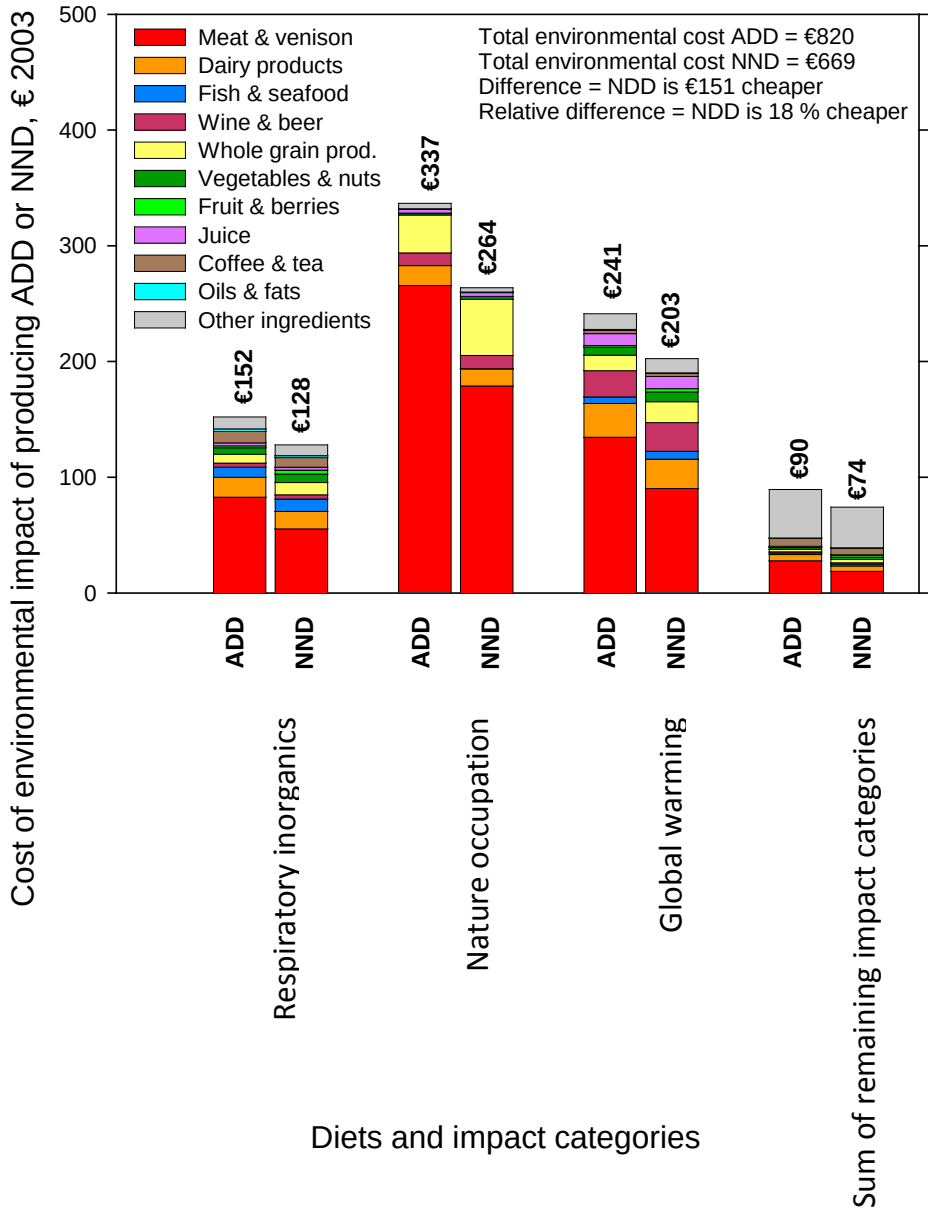

Figure 2 The potential environmental cost to society (shadow price) of the Average Danish Diet (ADD) and the modeled New Nordic Diet (NND).

Figure 3 compares the consumer price with the shadow price (potential environmental cost) of the two diets. The consumer price of the ADD was €2369/capita/year and of the NND €2585/capita/year when neither the price premium for organic production nor the savings by (mainly) having local produce in the NND was included (Figure 3). The increase in consumer price associated with the ADD-to-NND diet-shift was therefore €216 /capita/year, or a 12 % increase in consumer price, compared with ADD.

The potential savings (€151) reflected by the shadow price of the NND cover 70% of the increased consumer price (€216) for the NND. The environmental cost of driving a Euro class 5 car 1 mile was found to be 0.078 € per mile (Ecoinvent 2014). The savings caused by the diet-change (mainly caused by the lower meat content in the NND), equals the environmental impact of driving a EURO class 5 passenger car 1935 miles per year, i.e. a quarter of the average annual mileage for a Danish passenger car.

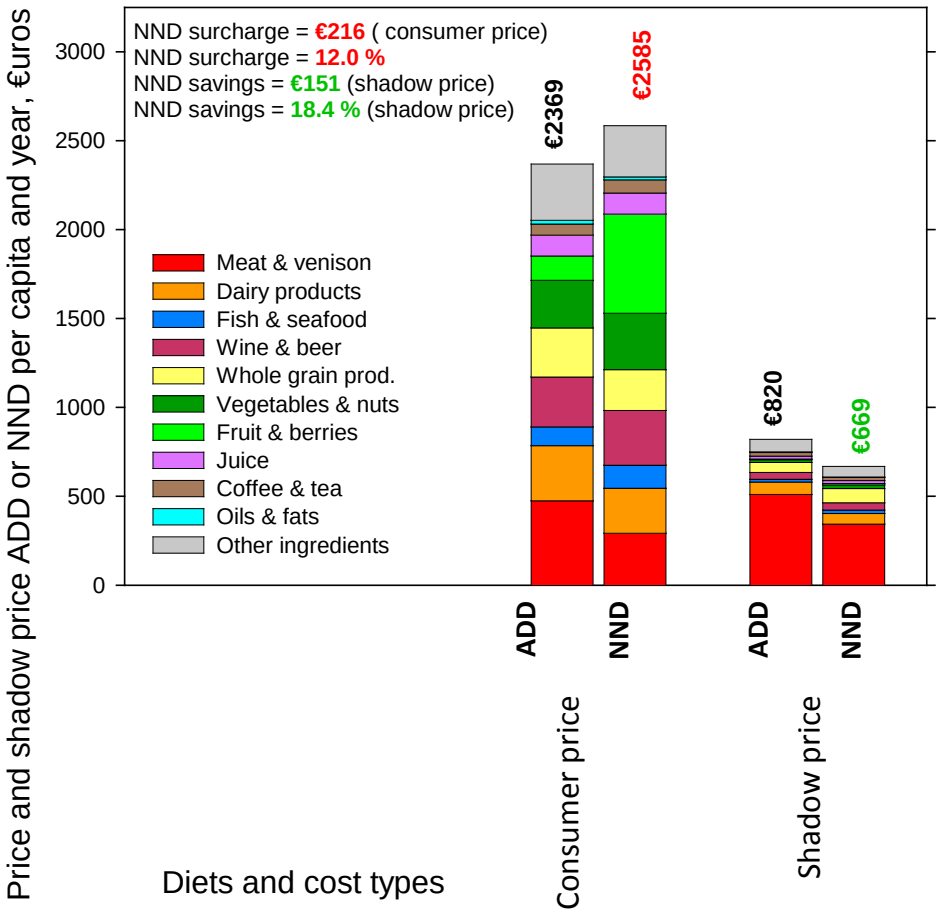

Figure 3 Consumer price of the modeled Average Danish Diet (ADD) and New Nordic Diet (NND) compared with the shadow price of the same diets.

Figure 3 also shows that the shadow price of the meat content in both diets exceeds the consumer price. For the ADD the shadow price exceeds the consumer price by €35.78 or 8%. For the NND the shadow price exceeds the consumer price by €51.46 or 18%. Reducing the meat content in either diet is consequently the most effective way to lower the impact of diets seen in a socioeconomic perspective.

The SW-ADD increased the kg intake relative to the ADD by 0.8%, while the main impact categories were decreased by 1.9-2.8% (data not shown). The consumer price for the SW-ADD increased by €96.54 or 4.1 %, over the ADD consumer price, while the shadow price decreased by €22.32 (data not shown), compensating for about a quarter of the consumer price increase.

4. Discussion

The prerequisite for trusting in the calculated reduced shadow price associated with the ADD-to-NND diet-shift is that (1) the Ecoinvent and the LCA food data are adequate for the purpose, and (2) that the Stepwise method calculates the environmental impacts correctly, and monetizes these impacts correctly. In this study, we assume both prerequisites to be fulfilled. It should however be mentioned that there are significant variations in findings regarding the economic value of some of the environmental benefits across studies, where some studies come out with lower shadow prices than those used in the present study.

The principles behind the OPUS NND have proved to be of great advantage to the environment, and to the potential socioeconomic savings associated with this healthy diet. The shadow price of the ADD-to-NND diet-shift was found to cover 70% of the increased consumer price of the diet-shift. In this study we have not included health advantages of the diet-shift, but since the NND was created to be a healthier diet than the ADD, it can be presumed that there will also be a socioeconomic advantage due to improved health when choosing the NND. All in all it may be cheaper to consume the NND than the ADD seen from a societal point of view – and this should be reflected in the price we pay for the ingredients of our diet. To have a direct consequence for the consumer prices, the Rio Declaration Principle 16 (1992, "the polluter pays principle") should be implemented for food consumption. Animal produce should be more expensive and vegetables and fruit cheaper. That would motivate more consumers to protect the environment and improve their health through their free choice of diet.

With the above in mind, it makes sense to consider further steps that make our diets even more environmentally friendly and socioeconomically beneficial. Saxe (2014) found that a vegetarian version of the NND could reduce the GWP by 67% when transport associated with imports of both the ADD and the NND was taken into account and by 59% when an 84% content of organics in the NND and the actual 8% content of organics in the ADD was taken into account. These reductions are more impressive than in the present study. One reason for this is that the ratio of meat types in the NND study by Saxe (2014) based on NND recipes was more advantageous. The recipes took into account that the production of beef, in particular (Cederberg et al. 2011), and pork is more harmful to the environment than is the production of grass-fed lamb, poultry, or fish. Relative to the distribution of meat types in the ADD, the NND in Saxe (2014) included only 30% beef and veal, 36% pork, and 73% chicken, but 680% grass-fed lamb and 820% venison. In the present study the meat content relative to the ADD was 68% beef and veal, 57% pork, 39% chicken and 98% lamb. Though the overall meat reduction in the present study was 39% vs. a 35% meat reduction in the study by Saxe (2014), the smaller reduction in beef and pork resulted in a smaller reduction in environmental impact in the present "real life" version of the NND. Another contributing factor to a lower effect of the NND on environmental impact was that import distances were not included in the present study.

The NND studies (Saxe 2013, Saxe 2014, and the present study) have shown that the diet composition, the meat quantum and meat type ratio, the transport distance of imported commodities and the inclusion of organics all affect the environmental impact of what we eat and drink. So we asked ourselves if there are *other* factors which could affect the environmental impact of a diet. The modeled substitution of soft drinks with a designer drink in the SW-ADD proved that in theory, manipulating with the sensory quality of what we eat and drink can affect our sense of satiety and thus make us eat less. Eating less effectively saves the consumer unnecessary expenses and saves society and citizens environmental impact and thereby reduces the shadow price of diets. Since two billion people worldwide are overweight or obese, a sensory improvement of our diets would not only increase the palatability, but also improve our health - by "manipulating" consumers to eat less.

There are indications that a high-protein diets are more satisfying (e.g. Padon-Jones et al. 2008), which may also be a way to decrease our intake, and thereby improve the general health and the environmental impact of diets.

5. Conclusion

This study supports the findings by Saxe (2014) that the OPUS NND is a surprisingly efficient tool in environmental protection – even when modeled in a "real-life" scenario based on expected consumer preferences; an instrument that can be further tuned and refined.

The increased consumer cost (284 €/capita/year) associated with an ADD-to-NND diet-shift is only partly (70 %) countered by the reduction in environmental costs (€151/capita/year) associated with the NND. Therefore,

only if the health benefits of the ADD-to-NND diet-shift is at least half of the environmental benefits, will it be a socioeconomic advantage to society if consumers prefer the New Nordic Diet over the Average Danish Diet. The potential savings associated with the reduced environmental impact of consuming the NND rather than the ADD is significant, as it equals a quarter of the environmental impact of driving a modern passenger car per capita and year.

The fact that the shadow price of a diet's meat ingredients, in contrast to the shadow price of all other ingredients was found to be higher than the consumer price, supports that a regulation of meat prices would be of singular importance for politicians and legislators when focusing on in future environmental regulation. The consumer should pay for the environmental (and health) impacts inflicted through their diet choices – no more, no less. That is the way of regulating the prices of automobiles, heat and power in Denmark. So why not apply the same instrument for food?

Though reducing the meat content in a diet seems to be the most efficient way to reduce the environmental impact of eating and drinking, there are obvious alternatives. One is to substitute a proportion of red meat with white meat, even when keeping the meet content constant. Another alternative is to eat less, either induced by our own free will (e.g. to "get in shape") or by seducing us to eat less through a higher protein content in our diet, or because of a higher sensory satisfaction e.g. via content of *umami* in your diet. Other alternatives include buying more local and less imported produce (which is true for most but not all commodities, Saunders et al. 2006), and overall buying less organics (or better, focusing on the environmentally friendly organics). The latter statement is based on comparing the monetized environmental impact of a range of organic vs. conventional products (Saxe 2014). Most organic produce has a higher overall environmental impact than their conventional counterpart.

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